RESEARCH HIGHLIGHT

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Occupancy-based Classification System for Design and Construction of Residential Basements

INTRODUCTION

This highlight presents a novel concept for a residential basement classification system that was developed during the "Performance Guidelines for Basement Envelope Systems and Materials" project, jointly undertaken by Canada Mortgage and Housing Corporation and the Institute for Research in Construction. For further information about the basement guidelines project, refer to the end of this *Research Highlight*.

Based on numerous past studies dealing with basement performance problems, and the ongoing periodic reporting of defects by new home warranty organizations, it is widely recognized that our conventional, "inherited" basement technologies do not consistently deliver the level of performance expected by today's consumers. In Canada, consumers now expect basements to potentially perform as livable spaces, offering the same quality environment as the rest of the dwelling. The "basement as a system" concept implies the need for rigorously assessing basement performance.

A system is an integrated assembly of interacting elements, designed to carry out cooperatively a predetermined function.

Unlike many parts of the U.S. and other warmer countries, where the basement is considered to be outside the building envelope, in Canada the basement is presumed to be inside the envelope: it is not only usable space, it is often considered to be livable. Although not necessarily lived in, the basement spaces (and heated crawl spaces) are connected to the above-ground spaces through passageways (and air circulation ducts in houses with forced-air systems). Indoor air, including its relative humidity, temperature and its contaminants, is shared with above-ground space. The National Building Code of Canada, which governs minimum requirements for basement spaces, recognizes this feature. These minimum requirements reflect constructions that can provide acceptable performance under some site conditions. These do not, however, always correspond to the actual—and often less-favourable—conditions under which many basements are currently constructed.

Building codes provide requirements to address only those issues that the construction community agrees require regulation. Consequently, current prescriptive building code requirements for basements do not necessarily preclude components and materials that may lead to substandard basement living space. As new components and materials are introduced—often without reference to the overall system—the likelihood of over- or under-designing basements increases.

A comprehensive framework of performance parameters is key to the successful design, construction and development of basement systems that will provide acceptable performance. Listing requirements of the basement envelope to provide livable space is not straightforward, and is even controversial, as there is no universal agreement on which functions are essential for a basement to be considered usable or livable.

BASEMENT SYSTEM FUNCTIONS

Table 1 provides a comprehensive listing of the functions of residential basement systems, which are divided into three related categories.

1. ***Performance Related*** – health, safety and functionality requirements
2. ***Construction Related*** – practicality and buildability requirements
3. ***Market Related*** – consumer demand and expectations requirements

These functions represent the minimum requirements needed for livable basements. However, it is important to recognize that it is the degree to which they are satisfied that is lacking consensus across Canada.

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Table 1 Functions of the basement envelope system

PERFORMANCE RELATED

- structural support
- earth retention
- control of heat flow
- control of air leakage, including soil gas
- control of surface emissions
- control of surface condensation
- control of interstitial condensation
- control of moisture flow into the envelope from the interior
- control of moisture flow into the envelope from the exterior
- control of rainwater, snow melt and groundwater
- control of sewer water
- control of light, solar and other radiation
- control of noise
- control of fire
- durability (that is, provide the above functions without premature failure over the service life of the envelope)

CONSTRUCTION RELATED

- be economical
- be buildable in a timely fashion, with available labour and materials
- be resistant to the rigours of the construction process, including weather, site storage and handling
- accommodate services—electrical, plumbing, HVAC, etc.

MARKET RELATED

Provide market value by

- being affordable
- being esthetically pleasing
- creating usable and livable space
- providing serviceable finishes (for example, flat, cleanable and supportive of furnishings and contents)

PROPOSED CLASSIFICATION SYSTEM FOR BASEMENTS

The basement guidelines project recognized that, while consensus had not been reached on minimum requirements for basements that satisfied the whole range of consumer expectations, there was an opportunity to develop an approach was consistent with the newly emerging objective-based codes.

During the development of these guidelines it became apparent that in Canada, there exist distinct regional approaches to, and expectations of, basement construction. Ideally, recognition of the diverse use of basements and expectations would be best served by a classification system based on intended use and the intensity, duration and frequency of environmental loads.

Table 2 proposes a basement classification system, which reflects the types of basements currently constructed across Canada.

- Class A basements (types 1, 2 and 3) represent basements in which all critical control functions for a livable space have been addressed. In many Canadian housing markets, Class A basements are dominant, maximizing the utilization of highly priced land, or adding value to smaller houses where the basement potentially represents nearly half of the livable floor area.
- Class B basements represent conventional practice in many parts of Canada, especially in areas with well-draining soils, where the risk of water leakage is of little or no concern.
- Class C basements represent what was once conventional basement construction up to the 1970s, and continues to be constructed in some parts of Canada where the notion of a livable basement is simply not marketable.
- Class D basements generally employ engineering design and special measures to deal with chronic flooding or sewer backup events.
- Class E basements are purely structural foundations, which provide no environmental separation. These are typically found in permafrost conditions and also for seasonal dwellings such as cottages, which are built on piers, posts or grade beams.

If the proposed classification system were nationally adopted—even informally—designers and builders could properly specify which functions they intend to address and to what degree in response to particular site conditions. This would promote the appropriate specification of systems and materials to address the required functions, based on intended use and the environmental loads. If basements were to be identified according to their class, homebuyers would know their basement's designed purpose and intended use. For new homebuyers, this would provide them an informed choice among alternative basement options.

The basement guidelines project largely focused on Class A-2 and A-3 basements, as these represent the majority of basements currently being built with new houses. Consumers may wish to be given the option of future upgrades to their basements that improve livability. For this reason, omitting certain control functions from a basement design is not only a matter of professional judgement, but also an important marketing issue. Therefore, it is recommended that all functions should at least be considered when designing basement systems.

Table 2 Proposed residential basement classification system

CLASS	INTENDED USE	SERVICE CRITERIA	LIMITATIONS/ALLOWANCES
A-1	Separate dwelling unit	■ Satisfies consumer expectations for control of heat, moisture, air and radiation. ■ Access/egress, fire and sound separation and fenestration meet all Code requirements. ■ Separate environmental control system. ■ Hygro-thermal comfort comparable to above-grade storeys of the dwelling.	■ Not suitable for flood-prone areas, or areas prone to sewer backup. ■ Basement can be finished with materials that are moisture-or water-sensitive. ■ Virtually defect-free construction. ■ Redundancy of critical control measures provided.
A-2	Livable space (for example, family room, home office, etc.)	■ Satisfies consumer expectations for control of heat, moisture, air and radiation. ■ Hygro-thermal comfort comparable to above-grade storeys of the dwelling.	■ Not suitable for flood-prone areas or areas prone to sewer backup. ■ Basement can be finished with materials that are moisture-or water-sensitive. ■ Virtually defect-free construction. ■ Redundancy of critical control measures provided.
A-3	Near-livable (for example, unfinished surfaces)	■ Satisfies all functions of the basement envelope, except for comfort, and is unfinished (for example, no flooring, carpet, paint, etc.)	■ Virtually defect-free construction. ■ Redundancy of critical control measures provided.
B	Convertible or adaptable basement	■ Satisfies minimum requirements for control of heat, moisture, air and radiation (for example, no explicit wall-drainage layer). ■ Thermal comfort can be upgraded to same quality as above-grade storeys of the dwelling. (for example, partially insulated wall)	■ Not suitable for flood-prone areas or areas prone to sewer backup. ■ All structural and interior finishing materials (if any) must recover to original specifications after wetting and drying. ■ Practically free of defects in free-draining soils where adequate site drainage has been provided. ■ Normal frequency of defects can be expected otherwise.
C	Basement/cellar—convertible or adaptable at significant future premium	■ Unfinished basement with no intentional control of heat, moisture, air and radiation.	■ Practically free of defects in free-draining soils where adequate site drainage has been provided. ■ Normal frequency of defects can be expected otherwise.
D	Basement serving a dwelling in a flood-prone area, or area prone to sewer backup	■ Class A-1, A-2 or A-3, B or C service criteria may apply.	■ Interior finishes capable of withstanding periodic wetting, drying, cleaning and disinfecting.
E	Basement acting as a structural foundation only	■ Acceptable factor of safety for structural performance, including frost-heaving, adhesion freezing and expansive soils.	■ Not intended to be inside the building envelope and no finishing projected. ■ Floor separating basement and indoors is now the building envelope and must address all functions. ■ Equipment in basement must be rated to operate outdoors or located in a suitably conditioned enclosure.

Note: Minimum requirements for health and safety are assumed for all the basement classes listed above. Only the structural safety requirements are addressed in Class E basements.

Critical control measure refers to materials/assemblies that control the flow of heat, air and moisture for acceptable performance.

FUTURE DIRECTIONS

The proposed residential basement classification system is a concept borrowed from other industry sectors. For example, many electrical components are certified and labelled according to a performance classification system that is derived from a codes and standards development process. A large and complex set of performance parameters is integrated into a classification system that is more easily understood and applied by designers, specifiers, inspectors, contractors and consumers.

As Canada's objective-based building codes evolve, the proposed basement classification system provides a good fit, allowing alternative solutions that can take advantage of emerging building materials and construction technologies.

In the meantime, the proposed basement classification system is a useful design and marketing tool that can help bridge the gap between consumer expectations and homebuilder practices.

PERFORMANCE GUIDELINES FOR BASEMENT ENVELOPE SYSTEMS AND MATERIALS: FINAL RESEARCH REPORT

A survey of new home warranty programs across Canada showed that the combined action of water and soils on basements was responsible for most major basement failures in new homes in 1994 and 1995. Frost action on basement walls was cited as a contributing factor in 40 per cent of the failures; swelling clays (resulting from strong fluctuations of wetting and drying in clay soils) were responsible for another 36 per cent; and frost action on the footings, a high water table and the presence of water-borne soluble salts contributed another 9 per cent, for a combined total of 85 per cent of all failure cases surveyed. This survey led the National Research Council (Institute for Research in Construction) to undertake a basement research project, which was guided by a large industry steering committee broadly representative of the issues. After completion of the research, a comprehensive publication on basement guidelines was developed. The guidelines will facilitate the design and construction of cost-effective basement systems that will achieve satisfactory performance in a cold climate like Canada's. They are intended for technical decision-makers in the homebuilding industry along with material manufacturers, home warranty agencies, building officials, as well as educators. The complete report is available at:

http://irc.nrc-cnrc.gc.ca/pubs/rr/rr199/index_e.html

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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